

Measurement of σ_{Total} in e^+e^- Annihilations Below 10.56 GeV

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Abstract. Using the CLEO III detector, we measure absolute cross sections for $e^+e^- \rightarrow \text{hadrons}$ at seven center-of-mass energies between 6.964 and 10.538 GeV. R , the ratio of hadronic and muon pair production cross sections, is measured at these energies with a r.m.s. error $< 2\%$ allowing determinations of the strong coupling α_s . Using the expected evolution of α_s with energy we find $\alpha_s(M_Z^2) = 0.126 \pm 0.005^{+0.015}_{-0.011}$, and $\Lambda = 0.31^{+0.09+0.29}_{-0.08-0.21}$.

1. Introduction

Theoretically $R(s) = \sigma_0(e^+e^- \rightarrow \text{hadrons})/\sigma_0(e^+e^- \rightarrow \mu^+\mu^-)$, where s is the square of the center-of-mass energy, provides a straight-forward way to measure the strong coupling α_s , since $R(s) = R_0 \left[1 + C_1 \frac{\alpha_s(s)}{\pi} + C_2 \left(\frac{\alpha_s(s)}{\pi} \right)^2 + C_3 \left(\frac{\alpha_s(s)}{\pi} \right)^3 + O(\alpha_s(s)^4) \right]$, where R_0 is given by the number of color degrees of freedom (3) times the sum of the squares of the quark charges. The C_i are determined by QCD calculations.

2. Analysis Method

The observed cross-section is the sum contributions from the bare cross-section corrected by soft photon radiation (including virtual higher order diagrams), σ_{sv} , a correction for hard photon radiation, σ_{hard} , and radiative tails from resonant states, σ_{res} . The “Born” cross-section, $\sigma_0 = \sigma_{\text{sv}}/(\epsilon(0)\delta_{\text{sv}})$, where $\epsilon(0)$ is the efficiency for events without initial state radiation and δ_{sv} accounts for soft photon emission and hadronic and leptonic vacuum polarization. More details of the analysis method and the results are available [1].

3. Selection Criteria

In order to suppress backgrounds from events other than $e^+e^- \rightarrow \text{hadrons}$, we apply selection requirements to individual tracks and showers as well as to entire events. These cuts are not completely efficient and thus we need to calculate their efficiencies from Monte Carlo simulation, thus leading to systematic errors, that dominate the uncertainties in our results. Table 1 lists the requirements for accepting tracks and showers and individual events.

Consistency with the beam collision point is enforced by the cut on d_0 , the distance of closest approach of the reconstructed track relative to the beam axis, and on z_0 , the distance between that point and the average collision point on the beam axis.

Table 1. Requirements on Track & Shower Selection, and Event Selection.

Track & Shower		Event	
Variable	Allowed range	Variable	Allowed range
χ^2/NDF	< 100.0	$ Z_{\text{vertex}} $	$< 6.0 \text{ cm}$
hit fraction	$(0.5, 1.2)$	$E_{\text{vis}}/2E_{\text{beam}}$	> 0.5
$ d_0 $	$< 3.0 \text{ cm}$	$ P_z^{\text{miss}}/E_{\text{vis}} $	< 0.3
$ z_0 $	$< 18.0 \text{ cm}$	H_2/H_0	< 0.9
error of z_0	$< 25.0 \text{ cm}$	$E_{\text{cal}}/2E_{\text{beam}}$	$(0.15, 0.9)$
$ \cot(\theta) $	< 3.0424	$E_{\gamma}^{\text{max}}/E_{\text{beam}}$	< 0.8
error of $\cot(\theta)$	< 0.50	$N_{\text{ChargedTrack}}$	≥ 4
$P_{\text{track}}/E_{\text{beam}}$	$(0.01, 1.5)$		
$E_{\text{shower}}/E_{\text{beam}}$	> 0.01		

4. Results

Besides estimating remaining backgrounds after these selection criteria are applied, we need to correct for beam radiation before annihilation interactions, that can then create $c\bar{c}$ and $b\bar{b}$ bound state resonances. When the resonance decays to hadrons, our observed cross section increases. For the purposes of our R measurement, these contributions are sources of background and must also be subtracted.

The sources of systematic uncertainty for each continuum cross section measurement include: luminosity, radiative correction, trigger efficiency for hadronic events, multiplicity correction, and hadronic event selection criteria. The resulting measured values of R as a function of energy are shown in Fig. 1.

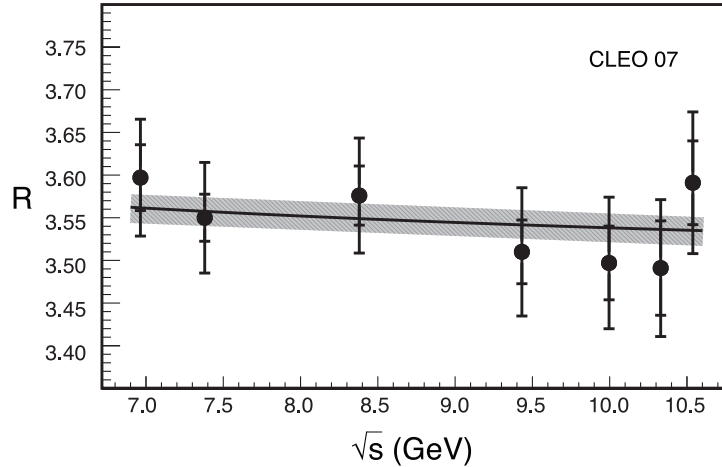


Figure 1. CLEO R measurements versus energy. The two sets of uncertainties represent combined uncorrelated and statistical uncertainties and total uncertainties; the line represents $R(s)$ with our average $\Lambda = 0.31 \text{ GeV}$, and the shaded area indicates the R -values corresponding to one standard deviation in the uncorrelated systematic uncertainty in Λ .

Table 2 shows the resulting α_s values obtained at each of the seven energies. Comparing α_s values with the QCD predictions [2] at our energies, which assumes the combined world average of $\alpha_s(M_Z^2) = 0.1189 \pm 0.0010$, we find agreement within our quoted uncertainties.

Table 2. Measured values of $\alpha_s(s)$ with statistical and systematic (common and uncorrelated) uncertainties, respectively.

\sqrt{s} GeV	$\alpha_s(s)$
10.538	$0.232 \pm 0.003 \pm 0.061 \pm 0.045$
10.330	$0.142 \pm 0.005 \pm 0.051 \pm 0.049$
9.996	$0.147 \pm 0.004 \pm 0.057 \pm 0.038$
9.432	$0.159 \pm 0.004 \pm 0.058 \pm 0.033$
8.380	$0.218 \pm 0.022 \pm 0.053 \pm 0.023$
7.380	$0.195 \pm 0.017 \pm 0.052 \pm 0.018$
6.964	$0.237 \pm 0.030 \pm 0.052 \pm 0.018$

To test the compatibility with other measurements of α_s we use the expected running of α_s with energy [3]:

$$\alpha_s(s) = \frac{4\pi}{\beta_0 \ln(s/\Lambda^2)} \left[1 - \frac{2\beta_1}{\beta_0^2} \frac{\ln[\ln(s/\Lambda^2)]}{\ln(s/\Lambda^2)} + \frac{4\beta_1^2}{\beta_0^4 \ln^2(s/\Lambda^2)} \times \left(\left(\ln[\ln(s/\Lambda^2)] - \frac{1}{2} \right)^2 + \frac{\beta_2\beta_0}{8\beta_1^2} - \frac{5}{4} \right) \right], \quad (1)$$

where n_f presents the number of quarks which have mass less than $\sqrt{s}/2$, Λ represents the QCD energy scale, and the β -functions are defined as follows: $\beta_0 = 11 - 2n_f/3$, $\beta_1 = 51 - 19n_f/3$, and $\beta_2 = 2857 - 5033n_f/9 + 325n_f^2/27$.

To find Λ , we use our α_s values at each energy point and solve Eq. (1), assuming n_f is equal to 4. The value of Λ varies from 0.11 at 10.330 GeV to 0.67 at 10.538 GeV. Using Eq. (1) with our average value of Λ , we extract the value of the α_s at $\sqrt{s} = M_Z$. Our results for α_s imply $\Lambda = 0.31^{+0.09+0.29}_{-0.08-0.21}$ GeV and $\alpha_s(M_Z^2) = 0.126 \pm 0.005^{+0.015}_{-0.011}$, where the uncertainties represent statistical and total systematic, respectively.

Our results for $\alpha_s(M_Z^2)$ and $\Lambda(n_f = 4)$ agree with the world averages $\alpha_s(M_Z^2) = 0.1189 \pm 0.0010$ [2] and $\Lambda(n_f = 4) = 0.29 \pm 0.04$ GeV [4]. Kuhn et al. [5] (LTH 749) include quark mass effects and different matching between 4 and 5 flavor effective theories They find using these data $\alpha_s(M_Z^2) = 0.110^{+0.010+0.010}_{-0.012-0.011}$ and $\Lambda = 0.13^{+0.11+0.11}_{-0.07-0.07}$ GeV.

Acknowledgments

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References

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